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The Role of Geomechanical Properties in the Process of Hydraulic Fracturing Propagation by using Fictitious Discrete Fracture Network Technique

Rouhollah Basirat, Kamran Goshtasbi* and Morteza Ahmadi

Rock Mechanics Engineering Group, Technical and Engineering Department, Tarbiat Modares University, Tehran, Iran

goshtasb@modares.ac.ir

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Abstract

Hydraulic fracturing is one of the conventional and common methods to stimulate oil and gas formations with low permeability. This method is widely used for creating artificial fractures and stimulate fluid flow in oil and gas wells. In this paper, fracture propagation process was simulated by using a Discrete Fracture Network (DFN) in UDEC software. Discrete Element Method (DEM) is a key for simulating hydraulic fracturing which is capable of performing a fully coupled hydromechanical analysis to model fluid flow through a network of fractures. In this regard, fictitious joints were used for modeling fracture propagation in a medium with equal to intact rock properties. To achieve this goal, the mechanical and strength properties of discontinuities were considered equal to mechanical and strength properties of intact rock. Then, the role of rock mechanics parameters including elastic modulus, cohesion and friction angle were studied in the process of fracture propagation. The results of numerical simulations showed that the extended fracture length is increased by increasing the elastic modulus and decreasing the friction angle. Also, increasing in the cohesion does not have a significant effect on the extended fracture length, but it reduces the hydraulic fracture opening.

Keywords: Hydraulic Fracturing, Discrete Fracture Network, Geomechanical Properties, Fictitious Joints, Fracture Propagation.

Introduction

Hydraulic fracturing is widely used to stimulate oil and gas formations with low permeability. This process involves injecting fluid into underground formations. The injection pressure increases until a critical value is achieved, and a fracture is initiated. The fracture will propagate away from the injection well and dilate as the injection continues.

Hydraulic fracturing can be broadly defined as the process by which a fracture initiates and propagates due to hydraulic pressure applied by a fluid inside the fracture [1]. There are various applications for hydraulic fracturing treatment including increasing the flow rate of oil or gas, connecting the natural fractures around the well, adjustment of pressure drop around the well, and etc. [2]. In the petroleum industry, determination of extended fracture in this process is important. Therefore, the effect of Geomechanical parameters such as elastic modulus, friction angle, and cohesion should be determined in this process.

In this regard, different numerical methods have been used to investigate the geometry and hydraulic fracturing propagation path which discussed in the reference [4]. Various researchers investigated the hydraulic fracturing propagation in the hydrocarbon reservoirs using different numerical methods [5-10]. In this paper, the effect of geomechanical properties in the process of hydraulic fracturing propagation is studied using Discrete Element Method (DEM) in UDEC software.

Methodology and Approaches

DEM is a key for simulating hydraulic fracturing which is capable of performing a fully coupled hydromechanical analysis to model fluid flow through a fractures network. Mechanical deformation of joint apertures changes conductivity and, conversely, the connectivity changes the joint fluid pressure, which affects the mechanical computations of joint aperture. DEM is a particular model that considers the process of flow and transfer of fluid into a fractured rock mass from a set of interconnected joints [11]. The propagation of hydraulic fracturing can be estimated by opened fractured during fluid injection.

In this paper, fracture propagation process was simulated by using Discrete Fracture Network (DFN). In this regard, fictitious joints were used for modeling of fracture propagation in a medium with equal to intact rock properties. To achieve this goal, the mechanical and strength properties of discontinuities were considered equal to mechanical and strength properties of intact rock. Also, the ratio of normal to shear stiffness is suggested equal to the elastic to shear modulus ratio [12]. Then, the role of rock mechanics parameters including elastic modulus, cohesion, and friction angle were studied in the process of fracture propagation. An analytical method (Kristianovich-Geertsma-de Klerk model) is also used for verification of numerical model. This analytical model is presented in the reference [13] completely.

Results and Conclusions

The obtained extended fracture length in numerical methods had a good agreement with KGD analytical model as an analytical approach. Therefore, this method (Fictitious DFN method) can be used for simulating hydraulic fracturing process. The results indicated that extended length is decreased by increasing friction angle, and its effect remained almost constant for values greater than 40 degrees. The shear strength is increased with increasing friction angle; therefore, more shear force is needed to expand fracture. This result proved by Ivars et al. [14] for underground tunnel application. The results of numerical simulations showed that hydraulic fracture length is increased by enhancing elastic modulus. In fact, by increasing the elasticity modulus of the rock, its brittleness value is increased, and therefore fracture length is increased. The relationship between the brittleness index and fracture propagation has been proved by experiments conducted by Liu et al. [15]. The results also presented that increasing in the cohesion does not have a significant effect on the extended fracture length, but it reduces the hydraulic fracture opening.

References

[1]. Guo B., Lyons C. W., Ghalambor A., *"Petroleum production engineering,"* Louisiana: Elsevier Science and Technology Book, 2007.

[2]. Economides M., *"Evaluation of impacts to underground sources of drinking water by hydraulic fracturing of coalbed methane reservoirs", Department of Energy,"* pp. 2-24, 2004.

[3]. Basirat R. and Goshtasbi K., *"The capabilities of different numerical methods to predict the crack propagation by hydraulic fracturing in hydrocarbon reservoirs,"* 2nd National Conference on Petroleum Geomechanics, Tehran, Iran [in Farsi], 2017.

[4]. Pak A. and Samimi S., "*Evaluating different approaches to the prediction of crack patterns induced by hydraulic fracturing in the stimulation of oil reservoirs and introducing a new approach,*" Petroleum Research, Vol. 22, Issue 72, February and March 2013, pp. 58-73, DOI: 10.22078/pr.2013.152, [in Persian], 2013.

[5]. Nagel N., Gill I., Sanches Nagel M. and Damjanac B., *"Simulating hydraulic fracturing in real fractured rock overcoming the limits of pseudoo 3D models,"* Paper SPE 140480 Presented at SPE Hydraulic Fracturing Technology Conference, Woodlands, Texas, USA, 2011.

[6]. Yao Y., *"Linear elastic and cohesive fracture analysis to model hydraulic fracture in brittle and ductile rocks,"* Rock Mechanics and Rock Engineering Journal. Vol. 45, No. 3, pp. 375-387, 2012.

[7]. Zhang, X. and Jeffrey, R.G. *"Fluid-driven multiple fracture growth from a permeable bedding plane intersected by an ascending hydraulic fracture,"* Journal of Geophysical Research, Vol. 117, B12402, doi:10.1029/2012JB009609, 2012.

[8]. Behnia M., Goshtasbi K., Fatehi Marji M. and Golshani A., *"On the crack propagation modeling of hydraulic fracturing by a hybridized displacement discontinuity/boundary collocation method,"* Journal of Mining and Environment, Vol. 2, No.1, pp. 1-16, 2011.

[9]. Behnia M., Goshtasbi K., Fatehi Marji M. and Golshani A., *"Numerical simulation of interaction between hydraulic and natural fractures in discontinuous media,"* Acta Geotechnica, DOI 10.1007/s11440-014-0332-1, 2014.

[10]. Behnia M., Goshtasbi K., Zhang G. and Mirzeinaly Yazdi S. H., *"Numerical modeling of hydraulic fracture propagation and reorientation,"* European Journal of Environmental and Civil Engineering, Vol. 19, No. 2, pp. 152-167, DOI: 10.1080/19648189.2014.939306, 2015.

[11]. Jing L. and Stephansson O., *"Fundamentals of discrete element methods for rock engineering: Theory and applications (developments in geotechnical engi-*

neering)," Amsterdam: Elsevier, 2007.

[12]. Wang S., *"Fundamental studies of the deformability and strength of jointed rock massesat three dimensional level,"* PhD Dissertation, University of Arizona, Tucson, 1992.

[13]. Economides M. J., Valkó J. P., Oligney R. E., *"Unified fracture design: bridging the gap between theory and practice,"* Orsa Press, 2002.

[14]. Ivars D. M ., *"Water inflow into excavations in fractured rock-a three-dimensional hydro-mechanical numerical study,"* International Journal of Rock Mechanics & Mining Sciences. Vol. 43, pp. 705–725, 2006.

[15]. Liu G., Zhang J., Lu H., Li S., Wu T. and Meng Z., *"Evaluation of rock mechanical properties to assist hydraulic fracturing in a tight oil reservoir,"* Materials Research Innovations, Vol. 19, sup. 8, S8-260-S8-267, 2015.